JOHN OF SACROBOSCO AND THE CALENDAR

by Jennifer Moreton

John of Sacrobosco was a thirteenth-century writer whose treatises on arithmetic, astronomy, and the calendar were copied and printed for hundreds of years; yet as Olaf Pedersen has observed, he is today "a mere name." Professor Pedersen, the most recent scholar to have commented on his writings, has collected what can be known or surmised about the man.[1] Today he is remembered mainly for his astronomical work, the *Sphere*.[2] His calendar treatise, the *De anni ratione*, has had no modern editor; but it is as a computist, or writer on the calendar, that his contemporaries knew him best. Whatever the relationship between the lines that appear to have been inscribed on his (no longer existing) tomb and the punning verses which can be found, in Philip Melanchthon's 1538 edition and in most of the manuscripts I have seen, both agree in commemorating Sacrobosco as the man who "divided time."[3]

The *De anni ratione* is different from Sacrobosco's other writings. In the *Algorism* and the *Sphere* new topics were being dealt with, or at any rate old topics were being dealt with in a new way; but there was a long and honorable tradition of writing on the calendar: a tradition which was to lead, eventually, to the Gregorian Reform of 1582.[4] The intention of this article is to examine the *De anni ratione* in its computistical context, in the hope of throwing light on some of the work's puzzling aspects. In the first place, what is Sacrobosco's contribution to the history of calendar reform? R. R. Steele suggested that he was the first writer to make "direct use of the new [Arabic] sources."[5] His use of them was, as I shall show, inaccurate. Inaccurate or not, material of this kind, embodying the "new science," was scarcely the stuff of an elementary treatise. It has generally been assumed that the *De anni ratione* was the standard computistical text for the medieval arts student. The second question to be considered, therefore, is whether this was so: that is, is it likely that inexperienced students would

[1]Olaf Pedersen, "In Quest of Sacrobosco," *Journal for the History of Astronomy* 16 (1985) 175–221.

[2]John of Sacrobosco, *De spere*: ed. Lynn Thorndike, *The Sphere of Sacrobosco and Its Commentators* (Chicago 1949).

[3]John of Sacrobosco, *De anni ratione*, ed. Philip Melanchthon (Wittenburg 1538) [fol. 55v]:

M. Christi bis .C. quarto deno quater anno
De Sacro bosco discrevit tempora ramus
Gratia cui nomen dederat divina Iohannes

All quotations in this article are from this edition, which is unfoliated; my foliation is contained in square brackets.

[4]See *Gregorian Reform of the Calendar*, ed. C. V. Coyne et al. (Vatican City 1983).

[5]R. R. Steele, ed., *Opera hactenus inedita fratris Rogeri* 6 (Oxford 1926) xx.

have been exposed to advanced, and, as will become apparent, unorthodox ideas at such an early stage in their careers? An examination of manuscript material has suggested an alternative, and more appropriate text. Finally, what is the meaning of the statement that Sacrobosco "divided time"? Only by setting the *De anni ratione* in the context of other treatises on the calendar, some of which, unfortunately, have never been printed, can these questions be satisfactorily resolved.

What, then, is this tradition? *Computus*, or *compotus*, to use its more commonly found thirteenth-century spelling, is a specialized application of computation or reckoning. The most important scientific textbook of the early Middle Ages was the Bible, and the Christian calendar is firmly based in Scripture. The authority of the Old Testament lays it down that God has set lights "in the firmament of heaven" to be "for signs, and for seasons, and for days, and for years" (Genesis 1.14). Solar movement provides the basis for dating the fixed feasts. To find Easter, an event placed in history firmly, if not unambiguously, by the narratives of the New Testament, it is necessary to collate solar and lunar movements. And hence the need for computation.

Until the beginning of the eighth century, computists were preoccupied with the need to find an accurate and generally acceptable method of dating Easter in any given year. It was a question which was settled for Latin Christendom by the adoption of the Dionysian Cycle. The use of this cycle was confirmed at the Synod of Whitby in 664, and perhaps more importantly, by the magisterial authority of Bede. But the old controversy was not entirely forgotten: the Carolingian schools preserved pre-Bedan texts as well as Bede's great works on time; and remnants of the argument are still to be found in the *De anni ratione* of Sacrobosco.

Irish scholarship lies behind the *De temporum ratione* of Bede;[6] and Irish scholars retained their interest in *compotus*. The hermit Marianus Scotus, who died at Mainz in 1094, calculated that the date of the Incarnation as given by Dionysius was twenty-one years too late.[7] In Sacrobosco's treatise there is no mention of Marianus; the controversy is discussed in relation to the eleventh-century compotist Gerland. Gerland's *Compotus*, which seems to have been very influential, particularly in England, has never been printed, although it occurs in numerous manuscripts.[8] Sacrobosco appears not to have known it at first hand: both he and Robert Grosseteste in his *Compotus correctorius* assumed that Gerland's cycle predated that of Dionysius by twelve years. In fact, Gerland concludes that there is an error of seven years.

By the period in which the *De anni ratione* was written, the controversy about the Christian Era seemed less important. After all, as the treatise points out, a cycle is a circle, and you can start a circle anywhere you like, without altering the intrinsic calculations.[9] More serious problems had emerged which related to the calculations themselves. It is here that we should look if we wish to assess the importance of Sacrobosco's contribution to calendar reform.

The first problem concerned the placing of the equinoxes and solstices in the solar

[6]See Bede, *Opera de temporibus*, ed. C. W. Jones (Cambridge, Mass. 1943), esp. 105–113.

[7]See A. Cordoliani, "L'activité computistique de Robert, évêque de Hereford," *Mélanges offerts à René Crozet*, ed. P. Gallais and Y.-J. Rion, 2 vols. (Poitiers 1966) 1.133.

[8]See A. Cordoliani, "Abbon de Fleury, Hériger de Lobbes et Gerland de Besançon sur l'ère de l'Incarnation de Denys le Petit," *Revue d'histoire ecclésiastique* 44 (1949) 463–487; idem, "Notes sur an auteur peu connu: Gerland de Besançon (avant 1100–après 1148)," *Revue du moyen âge latin* 1 (1945) 411–419, 2 (1946) 309–313.

[9]Sacrobosco (n. 3 above) [fol. 24v]: "in circulo contingat ubicunque volueris principium assignare."

year. The discrepancy between Alexandrian and Roman dating was one of the central issues in the Pascal Controversy. The argument in this case hinged on the date of the spring equinox, since it was an axiom of the compotists that Easter could not fall before it.[10] Later compotists came to ponder the question with regard to the winter and summer solstices. Traditionally these were held to be the dates of the birth of Christ and of John the Baptist. These dates were supported by the saying which the Fourth Gospel attributes to John the Baptist: "He must increase but I must decrease" (John 3.30), and by the Gloss, which interprets this text as referring to the lengthening and the shortening of the days which occur after these points in the year. It had, however, become evident that these feasts were no longer celebrated at the time of the solstices, but after them.

It eventually became clear that the crucial points in the solar year were slipping backward because the Julian calendar overestimated the length of the tropical year (that is, the year reckoned as the sun's passage from one solsticial or equinoctial point until its return to the same point). In 43 B.C., when it was established that the length of the tropical year was 365.25 days, it was in fact approximately 365.2422 days. The result was that while the Romans had reckoned that the equinoctial and solsticial points occurred around the twenty-fifth (viii kal.) of the appropriate month, later Alexandrian observations showed them to occur earlier, on the twenty-first (xi kal.) of the month. As time went on, the discrepancy between the actual solstices and equinoxes and their position in the calendar used by the church became more pronounced. The Gregorian Reform of 1582 amended the Julian calendar by omitting three leap years in every 400. A more accurate measurement would have resulted from the omission of one leap-day in every 128 years.[11]

Sacrobosco's solution to the problem of the drifting solstices is based on the value given for the length of the tropical year which he found in Book 3 of the newly-available *Almagest* of Ptolemy.[12] Modern writers, he tells us, are uncertain about the position of the solstices and the equinoxes. According to the old writers, the winter solstice should fall on 25 December (Christmas Day), the summer solstice on 24 June (St. John's Day). Sacrobosco argues that because of the overestimation of the Julian year, the winter solstice would originally have occurred six days before Christmas Day, and the summer solstice six days before Saint John's day. The Julian reckoning gives the mean value of the calendar month as 30 days, 10 hours, 30 minutes. The actual value, Sacrobosco says, is 30 days, 10 hours, 29 minutes, 36 seconds. The Julian reckoning is thus 24 seconds too long. In a year, the overestimation amounts to 288 seconds or one-twelfth of an hour, in twelve years to one hour, and in 288 years to one day. At the present time (which a later reference in the treatise gives as either 1232 or 1235)[13] Christmas Day and Saint John's Day are preceded by their respective solstices by a space of ten days. Since a period of 4 × 288 years has elapsed since these dates, at the time of the Incarnation the solstices must already have drifted six days back in the Julian calendar.[14]

There are two difficulties with Sacrobosco's explanation. The first is that it is inac-

[10]See Bede (n. 6 above) 20ff.

[11]See J. G. Whitrow, *Time in History* (Oxford 1988) 187.

[12]See Pedersen (n. 1 above) 208–209.

[13]Sacrobosco (n. 3 above) [fol. 38v]: "Sed ab incarnatione Domini elapsi sunt 1232 anni." Thus the printed edition, but most manuscripts have 1235—see Pedersen (n. 1 above) 189.

[14]See Appendix B below.

curate. One-twelfth of an hour is 300 seconds, not 288, a "rather careless approximation."[15] The second is that Sacrobosco's conclusion that the overestimation of the year, amounting to one day in 288 years, has resulted in a backward drift of the solstices of four days since the Incarnation is eccentric. Sacrobosco's calculations were consonant with the Alexandrian placing of the relevant date, but there was a general acceptance that the error of ten days or more dated from the Incarnation itself, and, indeed, by the thirteenth century, that the winter solstice fell about 13 December. In the *Compotus correctorius*, Robert Grosseteste, who was John of Sacrobosco's contemporary, based his calculations not on Ptolemy, but on the tenth-century Arabic astronomer Al-Bâttanî (Albategni). The latter posited an overestimation of one day in about a hundred years. This, Grosseteste says, is consonant with "the experience of our time." According to the scriptures, Our Lord was born at the winter solstice, which now precedes Christmas Day by about as many days as there are centuries from the Nativity.[16]

Sacrobosco rounds off his explanation with a commonly occurring mnemonic which does not necessarily contradict his thesis; but it puzzled one copyist, who was obviously used to counting the ten-day drift of the solstices from the Incarnation. And so he writes not *sic nunc est in decimo* in a preceding sentence, but *sic non est in decimo*.[17]

If, as Sacrobosco argues, the solstices had already drifted back by six days at the time of the Incarnation, where did they originally occur? His answer is given in an earlier passage about the solar year. Numa Pompilius, he tells us, began the year from the winter solstice. His authority for this is Ovid:

> Bruma novi prima est, veterisque novissima solis,
> Principium capiunt Phoebus et annus idem.[18]

Sacrobosco, following Ovid, takes 1 January as the original position of the winter solstice.[19] He was not the first to do this: the twelfth-century *Compotus* of a certain Master William (or possibly some notes appended to that work) contains the suggestion that the winter solstice was "perhaps" at first on 1 January, and quotes one of the lines above; but he goes on to say that the winter solstice is "now certainly proved" to fall on Saint Lucy's Day (13 December).[20] Sacrobosco's innovation appears to be in relating Ovid's lines to Ptolemy's value of the length of the year.

A further problem that preoccupied Sacrobosco and his contemporaries concerned what R. R. Steele happily called the "ecclesiastical moon."[21] The Dionysian Cycle assumes that 235 lunations, or synodic months, are equal to 19 solar or tropical years. After that period, the sun and moon should be realigned as they were at the beginning of the cycle. It is possible in theory, therefore, to plot the date on which Easter falls in a series of ninteen-year cycles in perpetuity.

[15]Pedersen (n. 1 above) 210.

[16]Robert Grosseteste, *Compotus correctorius*; printed by Steele (n. 5 above) 215: "Et hoc plus consonat ei quod invenimus per experimentum nostri temporis de antecessione solsticii. Quia secundum scripturam, Dominus noster Jesus Christus natus fuit in solsticio hiemali; nunc precedit solsticium Diem Natalem Domini circiter tot dies quot centenarii annorum ab eius nativitate transierunt."

[17]Copenhagen, Kongelige Bibliotek MS GKS 2° 277 fol. 93vb.

[18]Ovid, *Fasti* 1.164.

[19]Sacrobosco (n. 3 above) [fol. 19r–v].

[20]Oxford, Bodleian Library MS Digby 56 fol. 217ra: "cum primum erat solsticium hyemale forsitan in primo die ianuarii, unde Ovidius: principium capiunt Phebus et annus idem, nunc certissime probatur esse in die Sancte Lucie ante natale Domini."

[21]Steele (n. 5 above) vii.

The actuality was far less simple. One problem was easily recognized. Astronomical measurements used fractions, but the calendar could deal only with whole days. For example, as Bede and most compotists after him pointed out, the Julian year was 365¼ days long; but if this length of time were strictly adhered to, the New Year would start at four different points of the day—dawn, midday, evening, and midnight. The need to deal in whole days meant resorting to the exigencies of the bissextile with regard to the solar cycle, and the embolism and the *saltus lune* in its collation with the lunar cycle.

Less obvious at first was the inaccuracy of solar and lunar measurements. The observed position of the moon was affected by the inaccurate calculation of the tropical year, and the length of the lunation was itself overestimated.[22] In any case, even if they had been accurately measured, the two movements are incommensurable in practical terms. By the thirteenth century, the church calendar showed the new moon as falling three or four days later than it actually did: a fact that was obvious to any peasant, as Roger Bacon, writing in 1266, scathingly pointed out.[23]

Finding out where Easter should fall within the nineteen-year cycle had been made considerably easier by the invention of the Golden Number. This was a device which was apparently unknown to Bede, but which seems to have been familiar enough by the next century.[24] Sacrobosco describes it with considerable enthusiasm:

> Because it was easy and useful, the Romans wrote it in their calendars in letters of gold, and so it is still called the Golden Number.[25]

It was an enthusiasm shared by other compotists, since the Golden Number made calculation much simpler. In this system, each new moon (primation) is indicated by the figure 1 placed against the appropriate dates in the first year of the cycle, by 2 in the second year, and so on. What is important to remember is that 1 January = 3, since the new moon falls on 1 January in the third year of the cycle.

Sacrobosco explains the device, and incorporates into his text a metrical explanation of it which is to be found, among other places, in the *Massa compoti* of an earlier writer, Alexander de Villa Dei (fl. 1200).[26] Sacrobosco then points out that erroneous calculation has resulted in the Golden Number being placed three or four days late. Nevertheless, he says, because any changes in the calendar have been forbidden in the General Council, modern writers must sustain errors of this kind.[27] He was no doubt wise to include this *caveat*: the assumption that the First Council of Nicaea (A.D. 325) had authorized the nineteen-year cycle was buttressed by a belief in its angelic origin.[28]

[22]The mean synodic month was reckoned as 6940 ÷ 235 = 29.5319 days. Its actual value was 29.5306 days: see Whitrow (n. 11 above) 189.

[23] Roger Bacon, *Opus maius*, ed. J. H. Bridges (Oxford 1897) 276: "Etiam quilibet computista novit, quod fallit primatio per tres dies vel quatuor his temporibus, et quilibet rusticus potest in coelo hunc errorem contemplari."

[24]See A. van de Vijver, "Hucbald de Saint-Armand, écolâtre, et l'invention du Nombre d'Or," *Mélanges Auguste Pelzer* (Louvain 1947) 37.

[25]Sacrobosco (n. 3 above) [fol. 35r]: "Romani igitur numerum illum propter eius facilitatem et utilitatem in calendariis suis aureis literis scripserunt, unde adhuc aureus appellatur numerus."

[26]Alexander de Villa Dei, *Massa compoti*: ed. W. E. van Wijk, *Le Nombre D'Or: Etude de chronologie technique* (The Hague 1936) 53.

[27]Sacrobosco (n. 3 above) [fol. 38v]: "Sed quia in Concilio generali aliquid de Calendario transmutare prohibitum est, oportet modernos adhuc sustinere huiusmodi errores."

[28]See C. W. Jones, "A Legend of St. Pachomius," *Speculum* 18 (1943) 198–210.

Sacrobosco had a further, less contentious suggestion to make about the nineteen-year cycle. The church calendar, as has been said above, deals only in whole numbers. But the nineteen years of the cycle (if we exclude the extra day in the lunar cycle, which was dealt with by the device of the *saltus lune*) contain (365.25 × 19) = 6939.75 days. A period of (19 × 4) = 76 years is necessary, Sacrobosco says, before every calendaric factor has been accounted for, and the lunations occur as they did originally. He calls this period the "cycle of cycles."[29]

Sacrobosco's suggested emendation is interesting but not original. The *Compotus correctorius* of Robert Grosseteste contains a similar passage on the necessity of the seventy-six year cycle, and the *Kalendarium* of the latter writer contains tables illustrating this. More importantly, they show how the true position of the Golden Number should be plotted.[30] But both ideas appear in the *Compotus* of Roger of Hereford, which contains the *annus presens* 1176 in two places, and Grosseteste's *Kalendarium* appears to be closely modeled on the tables that appear in Roger's treatise.[31]

For the purposes of this article, I have concentrated so far on two specific computistical problems and Sacrobosco's treatment of them. The *De anni ratione* does, of course, contain other interesting material, some of which (although less than has been thought) originated with Sacrobosco. A second important question has to be considered. This is that although it has been generally accepted that Sacrobosco's treatise was the standard computistical text for the medieval arts student, there appears to be no evidence to support this view; and there are good reasons for thinking it unlikely.

To begin with, despite the assumption that has sometimes been made, there is no clear statutory evidence that the *De anni ratione* was used in the arts curriculum. The earliest reference to *compotus* in a university statute comes from fourteenth-century Oxford: before 1350, regulations laid down that those incepting as Bachelors of Arts must have heard, as well as the first six books of Euclid, and the *Arithmetica* and *Topica* of Boethius, "Compotum cum algorismo, et tractatum de spere."[32] Eight days are to be given to the study of each topic. There is a further reference for 1409: no one may be admitted as a Bachelor unless he has first heard and recited "Algarismus integrorum, Compotum ecclesiasticum, Tractatum de spera."[33]

Strickland Gibson, who edited the Oxford statutes, assumed that the *Compotus* referred to was the *De anni ratione*, and it is true that Sacrobosco's treatise is sometimes titled *Compotus ecclesiasticus*; but it should be noted that Sacrobosco is not mentioned by name until the sixteenth century. By this time, *compotus* had dropped out of the curriculum. Sacrobosco's *Sphere*, with its commentators, was still being studied, and it is this work which is specifically attributed to him.[34]

Our evidence for the inclusion of *compotus* in the arts course comes, as has been said, from Oxford, and from fourteenth-century Oxford at that. And here there is a

[29]Sacrobosco (n. 3 above) [fol. 47]: "Sic igitur in quatuor cyclis omnia ad concordiam reducuntur, unde istud temporis spatium cyclus cyclorum appellatur."

[30]See "Die Neumondtafel des Lincolniensis," ed. Arvid Lindhagen, *Arkiv for Matematik, Astronomi och Fysik* 11/12 (1916) 15–41.

[31]Oxford, Bodleian Library MS Digby 40 fols. 38–43v. Roger's treatise appears to survive only in this codex and in Cambridge University Library MS Kk.I.1.

[32]*Statuta antiqua Universitatis Oxoniensis*, ed. Strickland Gibson (Oxford 1931) 33.

[33]Ibid. 200.

[34]Ibid. 378, 390.

further difficulty. Although the earliest commentator on Sacrobosco's *Sphere* designates him as *Anglicus*, all the information we have about his scholarly career associates him with Paris.[35] And there appears to be no evidence that *compotus* was taught as part of the quadrivium in thirteenth-century Paris at all.

The evidence of statutes about the texts which were taught in the medieval schools of either Oxford or Paris is necessarily incomplete. Another way to approach the question is by examining manuscripts; and Professor Pedersen has placed the works of Sacrobosco in the context of other astronomical treatises by this method. He cites several codices from the thirteenth century; but it is not part of his purpose to show that the texts that they contain were specific liberal arts texts. Indeed, he describes one of them as an "early form of the medieval *Corpus astronomicum* . . . aimed at the education of *computistae*, or astronomers with a specialised interest in time-keeping."[36]

We are a long way here from liberal arts students. Arts students were, after all, boys of perhaps fourteen or fifteen, and often not noted for their application to their studies. It seems unlikely that a text containing unorthodox and advanced ideas would have been prescribed for them, particularly since the period of study, as has already been said, was a mere eight days.

It is worth turning again to the computistical tradition. To make sense of it, we must appreciate that it had two strands, the theoretical and the practical. Bede's profound work, the *De temporum ratione*, explained the principles of time-keeping, and placed the subject in its theological and philosophical context. Insular expertise in the subject traveled to the Continent with Alcuin, but the cathedral schools of the Carolingian empire demanded something more elementary. In the ninth-century *Visitation Articles* of Regino of Prum, for instance, the cleric is to be asked only if he knows the "lesser *compotus*, that is, the epacts, the concurrents, and the Easter terms, and so forth."[37] Various devices were invented to help him, in particular the mnemonic and the *compotus manualis* (the latter was a development of the finger-counting known to Bede and earlier scholars).[38]

What was true of students in the cathedral schools was equally true of the university student. To calculate the date of Easter it was not necessary to know all the intricacies of *compotus*; all that was needed was to understand how the Golden Number worked, or to commit to memory the metrical explanation of its rules.

That did not mean, of course, that advanced computistical study was not carried on, but it would appear to have taken place outside the elementary arts course. It is relevant in this context that quadrivial studies seem to have been pursued energetically in twelfth-century Hereford; but I can find no evidence to suggest that the *Compotus* of Roger of Hereford was ever studied as part of the elementary liberal arts curriculum in the schools.

The preface to Roger's work, part of which was printed by J. C. Russell, describes the controversy which had arisen in twelfth-century England about discrepancies in the calendar. The battle seems to have been between the proponents of the natural or

[35]Pedersen (n. 1 above) 181–182.

[36]Olaf Pedersen, "The *Corpus astronomicum* and the Traditions of Medieval Latin Astronomy," *Studia Copernicana* 3 (1973) 76.

[37]Regino of Prum, *De synodalibus causis vel de disciplinis ecclesiasticis*, PL 132.191: "si computum minorem, id est epactas, concurrentes regulares, terminos paschales, et reliquos sapiat."

[38]See Bede (n. 6 above) 184–185.

"scientific," as opposed to the ecclesiastical or "popular" *compotus*.[39] Roger's reference to the two types of *compoti* foreshadows the distinction made by Alexander de Villa Dei. The *compotus philosophicus*, Alexander tells us, deals with the accurate division of time; the *compotus ecclesiasticus* is concerned with church usage.[40] Alexander's own work, which, as he specifically tells us, is a *compotus ecclesiasticus*, was deservedly popular in the schools, since it was an easily learned metrical compendium of traditional information about the calendar, incorporating simple methods of finding and remembering important dates in the church year.

In the *De anni ratione*, Sacrobosco's concern is with the "exact division of time." His acquaintance with the attempts of scientific astronomers to find an accurate quantity for the year had demonstrated to him that calendar problems were not amenable to whole numbers, and he despises the "smatterers" *[scioli]* who try to use them in this way.[41] His treatise, therefore, should be classified as a "philosophical" rather than an "ecclesiastical" *compotus*, despite the fact that copyists on occasion consign it to the latter category. And all the evidence suggests that it was the "ecclesiastical," not the "philosophical," *compotus* which was the subject of study in the arts course.

For whom then was the *De anni ratione* written? In a paper concerned primarily with the *Algorism*, Guy Beaujouan discusses the discrepancy between the absence of official documents that mention Sacrobosco's works, and the evidence that they were in fact well known, and concludes that they must have been studied outside the regular curriculum.[42] For despite the lack of statutory evidence, it appears that advanced quadrivial studies *were* pursued at Paris, by such scholars as Peter de Marincourt. The latter was named by Roger Bacon as one of the two great mathematicians of the thirteenth century.[43]

What is of particular interest is Beaujouan's suggestion that Sacrobosco's mathematical work, the *Algorism*, was a derivative text, a commentary, indeed, on the *Carmen de algorismo* of Alexander de Villa Dei. For there is conclusive evidence that the *De anni ratione*, too, is a text of this kind. An examination of some of the manuscripts which have been thought to contain Sacrobosco's treatise has shown that the text copied there is not his work, but the elementary schools *compotus* on which it is demonstrably based. This has not been obvious because the two works have similar, though not identical, incipits. The *De anni ratione* begins

> Compotus est scientia considerans tempora ex solis et lunae motibus.[44]

The beginning of the earlier work, which occurs in numerous manuscripts,[45] is

[39]Oxford, Bodleian Library MS Digby 40 fol. 21. See J. C. Russell, "Hereford and Arabic Science in England about 1175–1200," *Isis* 18 (1932) 21.

[40]Alexander de Villa Dei (n. 26 above) 52.

[41]Sacrobosco (n. 3 above) [fol. 18v]: "Neque defectus illius quantitatem secundum veritatem propter diversitatis parvitatem possibile est inveniri, sicut in Almagesti dictione tertia a Ptolemeo reperitur. Hoc etiam sciolis computistarum suae licet professioni adversantibus sensibiliter ex eius causa congruit demonstrari."

[42]Guy Beaujouan, "L'enseignment de l'arithmétique élémentaire à l'Université de Paris aux XIIIe et XIVe siècles," *Homenage à Millas-Vallicrosa* 1 (Barcelona 1954) 100.

[43]Roger Bacon, *Opus tertium*, ed. J. S. Brewer, *Opera quaedam hactenus inedita*, Rolls Series 15 (London 1859) 34–35.

[44]Sacrobosco (n. 3 above) [fol. 4].

[45]See Appendix A below.

Compotus est scientia considerans tempora distincta secundum motum solis et lune.

Catalogers have sometimes, not surprisingly, confused the two. Further misunderstanding has arisen from two further versions of the same elementary text each with a different incipit and each attributed to Robert Grosseteste. Ironically, only these misattributed versions have received critical attention.[46]

This earlier treatise more often appears with no attribution but with the title *Compotus ecclesiasticus*. It seems to be less commonly found with the sort of advanced texts which Professor Pedersen describes as constituting the *Corpus astronomicum*, although it often occurs with Sacrobosco's *Algorism* and *Sphere*, which did, of course, become standard schools texts. It appears to have been studied in this context in Oxford as late as the fifteenth century.[47] Since Sacrobosco's work repeats much of the earlier treatise verbatim, it is not surprising that it is sometimes given the same title. Perhaps it is more significant that the *De anni ratione* is often called a *Nova compilatio*. What is unusual about Sacrobosco's treatise is that it is based very firmly on only one earlier work, rather than being an arrangement of material collected from a variety of sources.

A comparison of the *De anni ratione* and the *Compotus ecclesiasticus* will throw light on some of the puzzling aspects of the *De anni ratione*. More importantly, it will enable us to see what Sacrobosco's contemporaries meant when they said he "divided time," and thus to assess the true nature of his contribution to the history of calendar reform.

At the beginning of this article I observed that both Sacrobosco and Robert Grosseteste were mistaken in thinking that Gerland's calculations for the beginning of the Christian Era predated those of Dionysius by twelve years. An examination of the *Compotus ecclesiasticus* indicates the source of this error. It appears that neither writer knew Gerland's treatise except through the *Compotus ecclesiasticus*, where the same mistake occurs.[48]

Differences in presentation between the *Compotus ecclesiasticus* and Sacrobosco's *De anni ratione* suggest that they were written with different purposes in mind. Diagrams are not characteristic of texts produced specifically for the schools, which were intended to be "heard" rather than read.[49] Although some manuscripts of the *Compotus ecclesiasticus* have diagrams, they are generally in the form of marginal annotations, and are not integral to the text. The diagrams that accompany the *De anni ratione* are referred to specifically in the text, and are often executed by copyists with great care,[50] in texts which are evidently intended to be read, not listened to.

[46]Evidence that this is a misattribution is provided in Jennifer Moreton, "Robert Grosseteste and the Calendar," in *Robert Grosseteste: New Perspectives on His Thought and Scholarship*, ed. James McEvoy, Instrumenta Patristica (Steenbrugge, forthcoming).

[47]The evidence for this is in Oxford, University College MS 26. See Appendix A below.

[48]Gerland constructed new tables which showed that Dionysius had placed the Incarnation seven years too late. Earlier in his treatise he had shown that even on the basis of his own dating Dionysius was wrong, so that according to his calculations Christ must have died earlier than the thirteenth or later than the two hundred fiftieth year of his cycle. The writer of the *Compotus ecclesiasticus* appears to have concentrated on the earlier explanation, and, moreover, to have confused the Crucifixion with the Incarnation.

[49]Gillian Evans, "From Abacus to Algorism: Theory and Practice in Medieval Arithmetic," *British Journal for the History of Science* 10 (1977) 121, remarks on the "comparative rarity of diagrams or tables among the algorisms."

[50]The version in Cambridge University Library MS Ii.III.3, which Thorndike called a "splendid parchment volume," is a particularly fine example.

Moreover, references in the two texts suggest that they were intended for different types of student. Citations in the *Compotus ecclesiasticus* are from texts with which the young arts student might have been familiar from his trivium studies. Cicero, Boethius and Ovid are quoted, but the only contemporary writer referred to is John Beleth. The latter's *Summa de ecclesiasticis officiis*, which can be reliably dated to 1160–1164,[51] and which is a pleasantly-written manual for priests, is not usually quoted in computistical works. Sacrobosco uses material which can be found in Beleth's work, although he does not mention him by name; but more important in the *De anni ratione* is the citation of the newly-available scientific writers, Alfraganus and Ptolemy. The inclusion of these writers, which might have been inappropriate in a work for elementary students, is evidence that Sacrobosco's work is to be regarded as a *Compotus philosophicus*.

It remains to detail the most important difference between the treatises. In working out his solution to the problem of the shifting solstices, and in all his other calculations, Sacrobosco uses minutes and seconds. The inclusion at the beginning of his treatise of a description of an older system of time notation,[52] which seems at first glance to be a kind of fossil in the text, is an enigma which is solved by reference to the *Compotus ecclesiasticus*, where the earlier system is used for calculations that Sacrobosco replaces.

The problem of the shifting solstices had, in fact, a conventional solution, which appears in the earlier text: according to the anonymous author, the overestimation of the Julian Year amounted, in the old notation, to 8 moments. There were 40 moments in an hour, and therefore 8 moments is equivalent to 12 minutes, or one-fifth of an hour. The calculation is complicated for modern readers by the use of Roman fractions.[53] In five years, the overestimation will be equal to one hour, and in $5 \times 24 = 120$ years a whole day. 1200 years, the compotist tells us, or rather more, have elapsed since the Incarnation: and so there has been a ten-day backward shift in the solstices and equinoxes. The calculation is followed by the mnemonic which, as has been mentioned above, caused difficulty to one copyist of the *De anni ratione*.[54]

The solution to the backward drift of the solstices proposed by the *Compotus ecclesiasticus* is to be found also in the *Massa compoti* of Alexander de Villa Dei[55] and in two other *compoti* of the same period, neither of which has been printed.[56] It appears to have been commonly accepted by later writers, for instance Vincent of Beauvais.[57] It is in fact more accurate than Sacrobosco's solution, and closer to the solution that was eventually adopted.

[51]See John Beleth, *Summa de ecclesiasticis officiis*, ed. H. Douteil, Corpus christianorum, Continuatio mediaevalis 41 (Turnholt 1976) 30*–31*.

[52]Sacrobosco (n. 3 above)[fol. 4v]: "Partes temporis die sunt quadrans, hora, punctus, momentum, uncia et atomos."

[53]The system is described by Bede in chap. 4 of the *De temporum ratione*, in relation to *uncie*.

[54]See Appendix B below.

[55]Alexander de Villa Dei (n. 26 above) 58–59.

[56]Conrad of Strasbourg, *Compotus*, in Bruges, Bibliothèque municipale MS 528 fol. 1v; Peter of Bern, *Compotus de arte astronomie*, in Oxford, Bodleian Library MS Can. Misc. 71 fols. 5v–6. A passage in the *Compotus* of Master William (Bodleian Library MS Digby 56 fol. 216vb), which is perhaps not integral to the work, mistakenly assumes that the Julian Calendar underestimates the length of the year by one day in 120 years.

[57]Vincent of Beauvais, *Speculum naturale* bk. 15 (Venice 1591) fols. 111vb–112rb. This text appears to be corrupt, but the Douai edition of 1624 is similar.

But all these are examples of the ecclesiastical *compotus*, as defined by Alexander de Villa Dei, dealing with church usage; and we have already noted that Sacrobosco's concern is with the exact division of time. The traditional notation was inadequate for expressing the complicated calculations that were an essential part of the "philosophical" *compotus*, because its constituent parts were unequal (47 atoms = 1 *uncia*; 12 *unciae* = 1 moment; 40 moments = 1 hour). The calculation described above resorts to the clumsy Roman system of expressing fractions. This calculation is relatively simple; but the horrendous results of using the method for more complicated reckoning can be studied in the *compotus* of Roger of Hereford.[58]

What was needed was a more rational method of reckoning; and it appears that it is to John of Sacrobosco that the credit is due for realizing that astronomical measurements, which derived from the ancient Babylonian sexagesimal system, could be applied to the measurement of time. At the beginning of his treatise, he compares the astronomer with the computist: whatever the former determines about the fractions of time, he says, is for the sake of the motions of the stars; for it is his business to consider the motion itself, that of the computist to consider the divisions of time.[59] He goes on to detail the divisions of time in the traditional manner, but then he observes that astronomical fractions are uniform in the use of 60 to the smallest part of each whole;[60] and it is these fractions (minutes, seconds and even smaller divisions) which he uses for all his calculations.

Of course, Sacrobosco was not the first writer in the West to use the sexagesimal system: the credit for this appears to belong to Walcher of Malvern, or possibly with more justice to Petrus Alfonsi;[61] but it was used by these writers in an astronomical rather than a computistical context.

I have argued that the *De anni ratione* is a type of work which would have been inappropriate for the liberal arts curriculum, and that there is, indeed, no evidence that it was written for this purpose. The proposal of a seventy-six-year cycle can be found in the earlier *Compotus* of Roger of Hereford. Sacrobosco's application of Ptolemy's calculations to the backward drift of the solstices possibly originated with him, and I have seen it in no other *compotus*. Unfortunately, it is inaccurate, and his solution did not influence the 1582 Calendar Reform. But all the *compoti* I have seen which seem to have been written before the *De anni ratione* use the old method of denoting time; all those which seem to have been written after it use minutes and seconds. The system of time notation which Sacrobosco introduced is still in use (with modifications) today. It is this which his contemporaries thought worthy of recording on his tomb. Despite the fame of his *Sphere*, for them he was the *computista* who *tempora decrevit*—divided time.

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[58]See, for instance, Bodleian Library MS Digby 40 fols. 34v–35.

[59]"Quicquid enim astronomus de temporis fractionibus determinat fit gratia motus astrorum; ipsius enim est motum considerare, computistae vero temporum discretiones"; Sacrobosco (n. 3 above) [fol 4].

[60]Ibid. [fol. 5]: "Astronomica tamen per 60 usque ad minimum cuiuslibet integri uniformis est fractio."

[61]See C. H. Haskins, *Studies in the History of Medieval Science* (New York 1924; repr. 1960) 115–116.

APPENDIX A

Manuscripts containing the *Compotus ecclesiasticus*

I have identified the following manuscripts which contain the *Compotus ecclesiasticus*: there must be many more. Appendix B (below) contains an extract of an edition of the treatise based on London, BL Add. 27589, the first manuscript listed here. It is early (s. xiii), and it is clearly and carefully written. It shares the same textual tradition as Oxford, Corpus Christi College MS 293b, which is also thirteenth century; no variants from the latter appear in Appendix B, since one folio, which appears to have contained the pertinent passage, is missing from this codex.

Oxford, Bodleian Library MS Ashmole 1285, which is also thirteenth century, and Oxford, University College MS 26, which is fifteenth century, contain a version of the text that appears to be nearest to that used by John of Sacrobosco; but the *De anni ratione* has similarities with the other texts too, as a study of Sacrobosco's text with the listed variants will show.

Since it was not possible to produce a definitive edition of the treatise on the basis of a few examples of what was presumably a widely-disseminated text, it was tempting to assume a "standard" edition, familiar to Sacrobosco, and still in use in the fifteenth century. In this case, the Ashmole manuscript might have been the best base text for the edition. But material tends to accumulate around treatises of this kind (Dublin, Trinity MS 441 below is an exception, since it is an intentional abbreviation), and the Ashmole manuscript appears to contain extra material. None of the manuscripts is free from inaccuracies, but of the thirteenth-century texts, the Ashmole manuscript is the most carelessly written, with the most mistakes.

Oxford, Bodleian Library MSS Can. Misc. 71 and Bodl. 679 represent yet another textual tradition. Both appear to date from the late thirteenth or the fourteenth century.

The last two manuscripts listed were not suitable for collation. The Dublin manuscript, as has been said, is an abbreviated text; and Cambridge, Pembroke College MS 278 contains much additional material, and some important differences in the ordering of material.

It should be emphasized that most variations among the six collated texts are of minor importance, affecting order rather than content. The mixture of roman and arabic numerals is as they appear in BL Add. 27589. A similar (although not identical) mixture is to be found in all the cited manuscripts, and none appears to be consistent in their use.

I have modernized the punctuation.

London, British Library MS Add. 27589, s. xiii (Ba)

The *Sphere* of Sacrobosco (fols. 1–12) is followed by the *Compotus ecclesiasticus*, unascribed, but attributed by the cataloger[62] to Sacrobosco (fols. 13–27); this is followed by the *Algorism* of Sacrobosco (fols. 28–34). This codex includes the *Sphere* and the *Compotus correctorius* of Robert Grosseteste. The latter text, which is carefully ascribed by the copyist, was used by R. R. Steele as the basis for his edition of the *Com-*

[62] *Catalogue of Additions to the MSS in the British Museum in the Years 1864–1875* 2, ed. E. A. Bond (London 1877) 334.

potus correctorius, which was printed with the *Compotus* of Robert Bacon, *Opera hactenus inedita fratris Rogeri* 6 (Oxford 1926).

Oxford, Corpus Christi College MS 293b, s. xiii (cc)

Originally part of C.C.C. MS 293, which was divided into two volumes in 1910. The manuscript exhibits three different foliation systems. According to Coxe's foliation, the *Compotus ecclesiasticus*, which he attributes "perhaps" to John of Sacrobosco, occupies fols. 326–334.[63] It is immediately preceded by the *Sphere* (fols. 310–321) and the *Algorism* of Sacrobosco. The rest of MS 293b contains theological and medical texts, but the manuscript even in its divided state represents a collection of codices. One folio appears to be missing from the *Compotus ecclesiasticus*; it apparently contained the passage printed in Appendix B below.

Oxford, Bodleian Library MS Ashmole 1285, s. xiii (A)

The volume is a collection of fourteen books written in the thirteenth century or earlier. Fols. 90–117 contain, together with various notes on the calendar, the *Carmen de algorismo* of Alexander de Villa Dei (fols. 90–91); the *Massa compoti* of the same author (fols. 93vb–97); and the *Compotus ecclesiasticus* (fols. 107–117), described by the cataloger[64] as *Johannis de Sacrobosco liber de computatione temporis.*

Oxford University College MS 26, s. xv (U)

The copyist was John Hatfeld, whose name appears on fols. 25v, 90, and 121v. Hatfeld supplicated for the degree of B.D. on 11 November 1454; it was before this, presumably, that he copied these quadrivium texts, which comprise the *Algorism* of John of Sacrobosco (fols. 4–25); the *Compotus ecclesiasticus* (fols. 26–90), described by the cataloger[65] as being by either John of Sacrobosco or Robert Grosseteste; the *Sphere* of Sacrobosco (fols. 92–121); *Theorica planetarum*, attributed by the cataloger to Robert Grosseteste (fols. 122–143); a treatise *De vocibus animalium* (fols. 143–145); Thomas Bradwardine, *Tractatus de proportione* (fol. 146). It is interesting that the *Compotus ecclesiasticus* appears to have been a standard text even as late as the fifteenth century. John Hatfeld perhaps did not take his quadrivial studies too seriously: the manuscript, written in a large, sprawling hand, is decorated with many doodles, leaves and hominoid forms predominating.

Oxford, Bodleian Library MS Can. Misc. 71, s. xiii–xiv (C)

The manuscript includes the *Compotus de arte astronomie* of Peter of Bern referred to in note 56 above (fols. 5–14); two fragments of what appear to be the *Algorism* of Sacrobosco (fols. 17, 27–31); the *Compotus ecclesiasticus* (fols. 31v–41v), cataloged simply as *Tractatus de computo*;[66] and the *Massa compoti* (fols. 47–54) and *Carmen de algorismo* (fols. 55–58) of Alexander de Villa Dei.

[63]H. O. Coxe, *Catalogus codicum MSS qui in collegiis aulisque hodie adservantur* 2 (Oxford 1852) 129.

[64]W. H. Black, *A Descriptive, Analytical and Critical Catalogue of MSS bequeathed unto the University of Oxford by Elias Ashmole . . .* (Oxford 1845) 1046.

[65]Coxe (n. 63 above) 1.7.

[66]H. O. Coxe, *Catalogi codicum MSS bibliothecae Bodleianae* 3 (Oxford 1854) 478.

Oxford, Bodleian Library MS Bodl. 679, s. xiv (B)

The *Compotus ecclesiasticus* (fols. 65–75), ascribed here to Robert Grosseteste,[67] is immediately preceded by the *Algorism* (fols. 51v–56) and the *Sphere* (fols. 56v–64) of John of Sacrobosco. The codex contains also Gundissalinus, *De divisione philosophie* (fols. 1–19); William of Conches, *De philosophia mundi* (fols. 77–97); Adelard of Bath, *Questiones naturales* (fols. 108–127v).

Cambridge, Pembroke College MS 278, s. xiv

This manuscript includes the *Compotus correctorius* of Robert Grosseteste (fols. 1–24); the *Compotus ecclesiasticus* (fols. 25–61);[68] the *Sphere* of Sacrobosco (fols. 61–69). The version of the *Compotus ecclesiasticus* in this manuscript has been "worked over" in the manner of the schools commentators: there is a different ordering of sections, and it contains much additional material.

Dublin, Trinity College MS 441, s. xiv

This codex, which contains much scientific material of an advanced kind, was once owned by John Dee. It includes the *Sphere* (fols. 69–74) and the *Compotus correctorius* of Robert Grosseteste, and the *Algorism* of John of Sacrobosco (fols. 99v–104), cataloged as a commentary on the *Algorismus* of Alexander de Villa Dei. The *Compotus ecclesiasticus* (fols. 104v–111) is copied here in an abbreviated version and attributed in the list of contents to Robert Grosseteste.[69]

APPENDIX B

The backward drift of the solstices: parallel passages in the *De anni ratione* of John of Sacrobosco and the *Compotus ecclesiasticus*:

1. *[De anni ratione]* Sed quod solstitium hyemale fuerit in die sexto tempore nativitatis Domini ante eius ortum, aestivale sexto die ante nativitatem beati Iohannis Baptistae, ostendi per hoc videtur quod cursui solis plus temporis quam debeat attribuitur. Unde et retrocedunt solsititia et aequinoctia, quantum ad veritatis sensibilitatem sol moratur in quolibet signorum per 30 dies et 10 horas et 29 minuta et 36 secunda, licet 30 minuta minus complete una medietas horae unius supponantur, prout in praedictis sensibiliter exprimitur. Unde una centesima et quinquagesima pars unius horae, scilicet 24 secunda, in omni superflue computantur signa. Et cum 12 sint signa, erunt duodecies 24 secunda, ex quibus in unum redactis pars horae duodecima conficitur. Sic igitur in 12 annis hora una integrabitur. Unde cum dies naturalis ex 24 horis constet, in duodecies 24 annis, hoc est in 288 annis, dies unus naturalis superfluere reperietur.

[67]F. Madan and H. H. E. Craster, *A Summary Catalogue of Western MSS in the Bodleian Library* 2.1 (Oxford 1922) 443.

[68]M. R. James, *A Descriptive Catalogue of the MSS in the Library of Pembroke College, Cambridge* (Cambridge 1905) 253.

[69]M. L. Colker, *Trinity College, Dublin: A Descriptive Catalogue of the Medieval and Renaissance MSS* (London 1991) 871.

Nunc igitur cum in die 10 solstitium hyemale nativitatem Domini die nativitatis computato, aestivale Beati Iohannis Baptistae antecedat (quod diversis lucescit rationibus), et non nisi quater praedictus numerus ab annis Domini subtrahi possit, relinquitur quod tempore nativitatis Domini et beati Ioannis in sexto praecesserit solstitium, et sic nunc est in decimo. Idem etiam respectu annunciationis Dominicae et conceptionis Ioannis Baptistae de aequinoctiis invenitur. Unde versus:

> Solstitium decimo Christum praeit atque Ioannem.
> Nuncia sic matris nox aequa, diemque Ioannis.[70]

2: *[Compotus ecclesiasticus]* Quod autem solsticium fuerit hiemale in nativitate[71] Domini, solsticium[72] estivale in nativitate[73] beati[74] Johannis Baptiste, videtur probari[75] hac[76] auctoritate Mathei[77] de beati Johanne:[78] *Illum oportet crescere me autem minui*;[79] quia dicit[80] quedam glosa[81] quando[82] Dominus natus erat[83] dies incipiebant[84] crescere, quando[85] autem Iohannes[86] decrescere. Set[87] licet tunc[88] hoc fuerit verum,[89] in nostro tempore non est ita, quia recesserunt[90] equinoctia et solstitia per hoc quod attribuimus cursui solis plus temporis[91] quam deberet attribui, quantum enim ad veritatem sol moratur in quolibet signo per[92] 30 gradus et 30 trientes hore et 29[93] bisse momenti. Unde in quolibet signo[94] computamus[95] superflue unum bisse, et cum xii sunt signa, erunt[96] xii bisse momenti, qui valent 8 momenta, id[97] est quintam partem hore.[98] Et ita in 5 annis computamus superflue unam horam. Et cum 24 hore faciunt unum diem naturalem, in quinquies 24 annis invenitur[99] superflue unus dies naturalis, id est[100]

[70]John of Sacrobosco (n. 3 above) [fols. 28v–29].
[71]die natale U
[72]et solstitium A; BC *omit*.
[73]die U
[74]sancti BU
[75]sic patet A; videtur U
[76]AU *omit*.
[77]beati mathei A
[78]B *omits* mathei de beati iohanne; iohanne qui dicit U
[79]C *omits* videtur probare——minui; B *adds* hec sunt verba beati iohannis baptiste.
[80]quia dicit: dicit enim ibi AU; ubi dicit BC
[81]glosa super quod C; glosa quod AUB
[82]cum BC
[83]est B; esset C
[84]incipiebat A
[85]cum U
[86]Iohannes natus erat incipiebant U
[87]et BA; AU *omit*.
[88]Ba *omits*.
[89]tempus verum C; temporis verum B
[90]retrocesserunt U
[91]tempore C
[92]U *omits*.
[93]per 30 B
[94]anno B; anno superflue C
[95]computatur C; computantur B
[96]BC *omit* unum bisse——erunt.
[97]et id U
[98]unius hore BCU
[99]innumeratur B; numeratur C
[100]BC *omit* id est.

in 120 annis. Set a nativitate Domini elapsi[101] sunt 1200 anni et eo amplius, in quo numerus sunt decies centum et decies viginti;[102] et ita per decem dies recessit[103] iam solsticium hiemale a nativitate Domini, et estivale[104] a nativitate beati[105] Iohannis Baptistae. Similiter intelligendum est de equinoctiis. Unde versus:

> Solsticium x[106] Christum preit atque Iohannem,
> Nuncia[107] sic[108] matris nox equa diemque[109] Iohannis.[110]

[101]lapsi U
[102]decies viginti: 2 B; viginti U
[103]retrocessit AUBC
[104]solsticium estivale BC
[105]C *omits*; sancti U
[106]decimo scilicet die B
[107]et nuncia U
[108]sicut B
[109]diesque BC
[110]Jennifer Moreton, "*Compotus ecclesiasticus*: An Early Thirteenth Century Compotus in Its Context, Ph.D.Thesis (Trinity College, Dublin 1992) 229–231. Sigla as in Appendix A above.